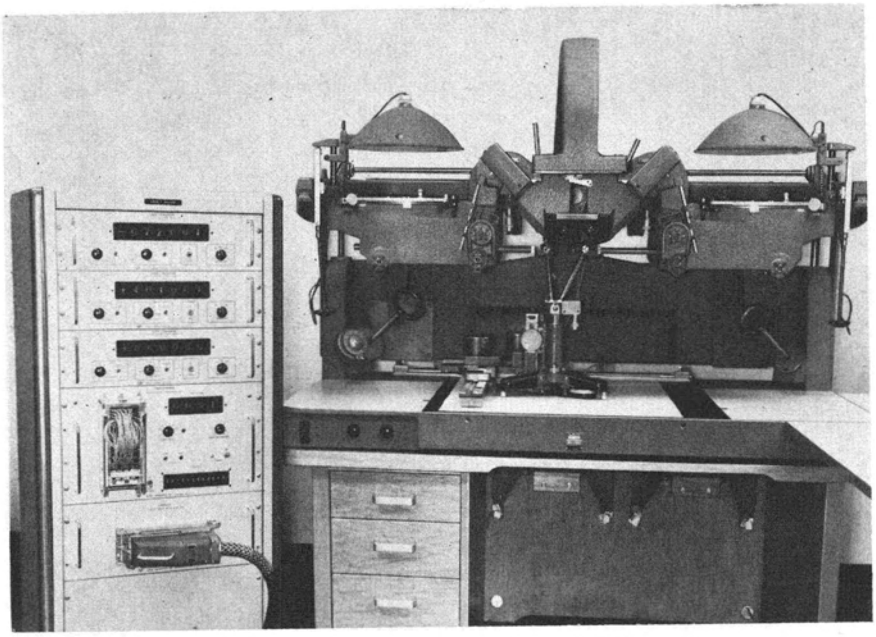

FRONTISPIECE. The B8 Aviograph with Digital Readout.

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Digital Readout for the B8 Plotter

The Faul/Coradi Coradograph and the Wang encoding system are incorporated into the Wild instrument.

(*Abstract on page 203*)

WILD HEERBRUGG PIONEERED in the adaptation of coordinate printers to their various analog instruments, and as a result the EK series of printers has been offered with the A7 (Figure 1) A8 and A9 Autographs for several years. Several hundred of these instruments are in use: the A7 and A9 Autographs for triangulation and cadastral work, and the A8 for the production of topographic maps at all scales.

The B8 Aviograph (Frontispiece) has been a popular adjunct to the Wild line of plotters, and is particularly applicable to the U. S. market because the free-hand motion of the tracing table is identical with the mode of operation of projection-type plotters. This means that an operator trained on projection plotters can be immediately productive on the B8. The B8 can be used in a lighted room free of partitions and it is capable of plotting from either wide-angle or super-wide angle photography, in color as well as black-and-white.

ONE OF THE PRINCIPAL applications of photogrammetry today is the determination of earth quantities to be moved in highway

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construction work and other civil engineering projects. The design of the B8 Aviograph, however, does not permit the attachment of the EK5 coordinate printer due to the lack of handwheels. Therefore, it is necessary to have some sort of positioning and recording device for the free-moving tracing table if a digitizing system is to be added to the instrument.

The model KDB-5050 Faul/Coradi Coradograph of Swiss design was chosen due to its rigidity, simple construction and proven reliability. In this application it is used in the metric form without tool holders, scales, tapes, verniers or dials because the relative position of the tracing table in X and Y is registered by Wang Model 52-500 Incremental Encoders. The encoders are attached by brackets, and suitable gearing is added at the Wild factory in Farmingdale, N. Y. A plate is also mounted on the slide of the Coradograph to attach the tracing table firmly to the unit. A Model 44-100 Wang encoder is affixed on the tracing table for the Z-measurement.

It should be noted that this system is immediately applicable to existing B8 aviographs. It is only necessary to send the tracing table to Wild for the addition of the Z-encoder; then the complete system is delivered ready for operation. Provision is made in the attaching device to orient the coradograph correctly with the neat model area of the B8. The prototype of this system at the research center, topographic division, U. S. geological survey, McLean, Virginia is shown in the Frontispiece.

WANG LABORATORIES INC. of Tewksbury Mass., was selected as a partner in this venture because a reliable, solid-state, digital conversion system was desired which would incorporate both digital display and compatibility with the several methods which are used for computer input. Both Wang Laboratories and Thomas L. Faul Associates, cooperated with Wild Heerbrugg Instruments in working out the problems attendant to combining their respective units, already field proven, into a compact system. No experimental components are involved; each element is a standard commercial item produced on a production basis.

THE FUNCTION OF the digitizing systems is to convert angular rotation, transformed from linear and height displacement of the Wild B8 and the Faul Coradograph, into digital form. In digital form, position information in three axes is displayed by six decimal digits. All data, including event number, the pre-data, etc., are serialized and outputed onto IBM card punches and/or electric typewriters. Other output devices may be used as well, and they will be discussed shortly.

A block diagram of the system is shown in Figure 2 which is necessarily simplified to show only the functional or logic components.

The physical appearance of the operating unit is shown in Figure 3.

To understand this system better, first let me explain the operation of the shaft angle to digital encoders. shaft angle encoders fall into two basic types: absolute and incremental. The absolute encoders provide a parallel output of many decades, and that output may be translated from the encoder code into decimal display. The absolute encoders have a fixed zero point, which may be desirable, but they are larger and heavier.

Incremental encoders, on the other hand, are small and light weight. They are basically two-phase rotary pulse generators, providing a two-phase square wave output where one phase leads or lags the other by 90 degrees. So furnished, incremental encoders are bidirectional devices in which output pulse counts may be either added or subtracted from an existing count. They lack the absolute encoder feature of a fixed mechanical zero, and if power is removed from the counting or accumulating device, the count is lost so that upon restoration of power to the counter, the counter assumes a random number. In photogrammetric applications this is not a disadvantage because the zero reference

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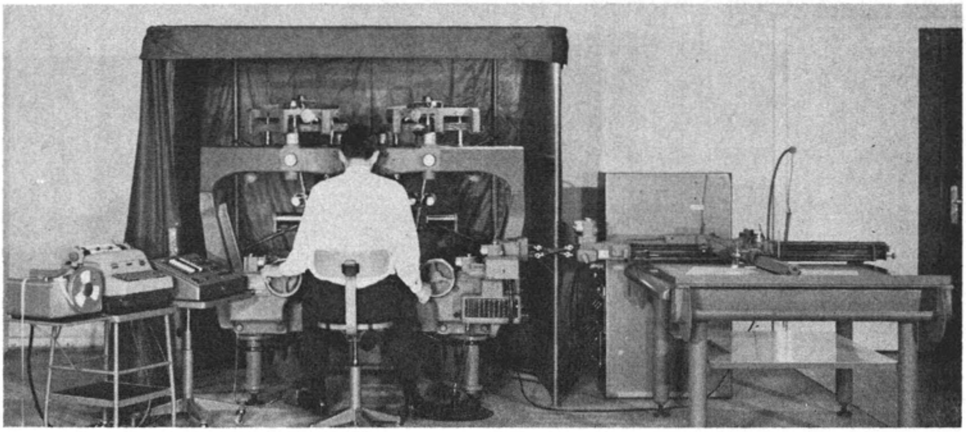

FIG. 1. The A7 Autograph with the EK5 digital readout.

point, or any point of interest, is located on the diapositive image and not on the frame of the plotter. Because the tracing table of the B8 is moved freehand, the advantages of the smaller size and lower weight of the incremental encoders made their choice logical. Their operation is illustrated by Figure 4.

A glass or metal disc is attached to the rotating shaft. On this disc are two concentric rows of windows located on the outer perimeter of the disc. These windows are of alternate light and dark areas such that light is transmitted for the width of one window and then blocked for an equal included angle. One row of windows is offset from the other by an arc of one-half the width of one window. High speed silicon diodes are used to sense the presence of light transmitted through the code disc, their outputs are amplified by two stage silicon transistor emitter follower amplifiers, and the output of these amplifiers is shown in Figure 4. The wave form shown depends on a constant rotational speed of the encoder. Outputs are in DC level shift form; therefore, the presence or absence of angular velocity has no effect on accuracy.

The two-phase square wave outputs shown in Figure 4 are fed to the bi-directional counters furnished for each axis. These operate by counting pulses generated usually at the leading and trailing edges of each of the two square wave output phases. If (in the normal mode) output A precedes output B, pulses are added. An ingenious little logic module, however, provides for the possibility

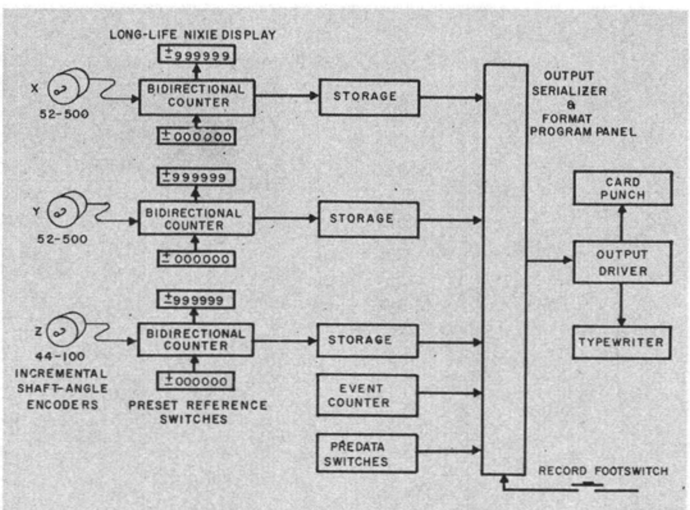

FIG. 2. Flow diagram of the digitizing system.

that output B may suddenly lead output A. In the latter case, counts are then subtracted from the bi-directional counter. The bi-directional counter operates from 000000 and counts to 999999 counts. This counter may be preset to any desired count within its range, including both positive and negative values. This is accomplished by front panel thumbwheel switches; alternately it may be reset to zero. If the coordinates of a given reference point in the stereo model are known, the tracing table is positioned on that point, the coordinate information is set into the counters, the "preset" pushbutton switches are operated, and the recording progresses from that point.

Other data must be recorded, such as scale factor settings, identification numbers, and other constants, for computer sorting or computation. Post data may also be of interest and recorded after the completion of a series of measurements. Provision must, therefore, be made for the entry of one or both types of data, and it is generally desirable to number each successive recording for computer sorting. An event counter is, therefore, furnished, and it is often necessary to preset this counter to a desired starting point. Predata switches and the event counter are furnished as an integral part of the system programmer enabling one to serialize all data for output reading. A typical serializer is shown in Figure 5. Programmable output format is desirable to allow for variations in the type of data being used. System versatility is considerably improved and it is far simpler to add additional output devices as necessity dictates.

THE PROGRAMMING is most commonly done with a program patch panel utilizing plug wires inserted into the rear of a connector which mates with the program panel shown on Figure 5. note that at least 64 serializing time pulses are provided which will almost fill an 80 column IBM card. All data points are presented on the program panel and, additionally, such codes as space, stop, etc., are shown.

The output of the programmer is in effect amplified by the output drivers which are high-power digital switches actuated serially by the programmer. Although this is equivalent to analog, amplification, it is free of the difficulties inherent in analog circuitry such as periodic adjustment to standardize gain. The high-level output is fed directly to output devices involved, such as in the instance (now under discussion) where both the IBM 526 or 026 Card Punch and the IBM model B Output Writer are actuated. The typewriter provides tabulated, easily-read results, and the IBM cards provide a computer-compatible output in Hollerith code for subsequent processing by a full-scale computer. Standard computer corrections for earth curvature, film shrinkage, and orientation of axis can be introduced at this time.

THE SYSTEM PROVIDES a continuous display of position. The output recording rate is governed by the maximum recording speed of the output devices being used. Thus, with a high-speed output device, such as an inexpensive, incremental, magnetic tape recorder, a continuous line-recording may be approximated by registering a series of points quite close together.

In the use of this equipment for cut-and-fill determinations where salient points are recorded, the user must choose between punch cards and computer-compatible punched tape. The choice is dictated by a number of

ABSTRACT: *The Wild B8 Aviograph, which is normally equipped with a tracing table and a pantograph for the compilation of topographic maps, can now be readily adapted to output the resultant data in digital form. The adaptation, sponsored by Wild Heerbrugg Instruments, Inc., applies two standard products of current manufacture: (1) the Faul/Coradi Coradograph, Model KDB-5050; and (2) the encoders and digitization system of Wang Laboratories, Inc. Each of three rectangular coordinates of points are recorded to six digits in addition to an event counter. The data are displayed on nixie tubes and may be recorded on typewriter, punch tape, punch cards, and/or magnetic tape. The accuracy of the system is 0.01 mm. at the scale of the stereoscopic model. Replaceable plug-in printed-circuit modules in the electronic equipment facilitate service operations.*

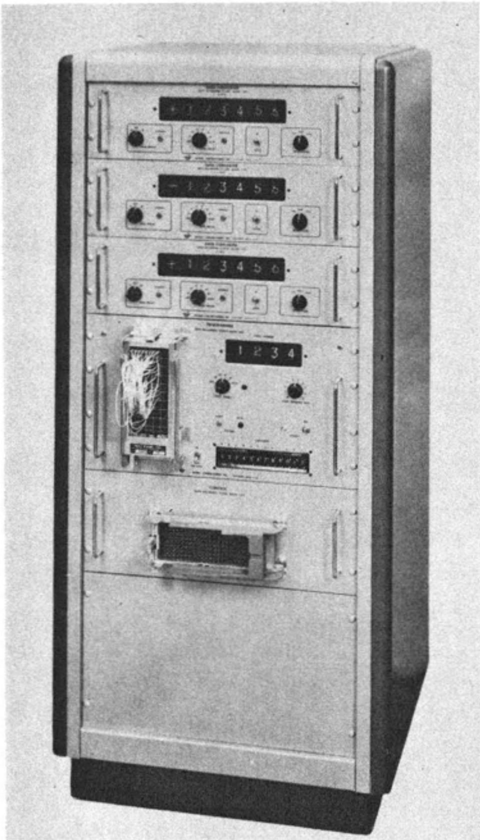

FIG. 3. The 2300 Readout Recording System supplied by Wang Laboratories, Inc.

considerations such as type of computer and speed of operation, due to the fact that card punches are relatively slow devices. It is probably sufficient to point out in this presentation that either device is compatible.

THE SYSTEM ACCURACY is basically ±1 count, or one increment of resolution. This means that the encoders are designed to read a displacement of 0.01 mm. in the B8 model. (The accuracy of neasuring will be slightly lower than this because of the freehand motion.)

The principal source of error within the encoder is eccentricity and the accuracy of the original layout of the code disc. Extreme precautions are exercised in each manufacturing step, such as making the 2½-inch code disc in the 52-500 encoder by photographic reduction from a master which is three feet in diameter. The code disc is aligned to the shaft with the use of a high-powered microscope, and similar care is exercised in each step of the manufacturing process.

The bi-directional counter can be ignored as a source of error. It is well shielded against stray "noise" pulses from outside sources. The serializer and output driver are similarly inherently free from error, as well as the output devices, except for outright malfunction.

MALFUNCTIONS, however, may occur. It can safely be assumed that any complex assembly of components, whether they be mechanical or electronic, may fail at some time or other. It is therefore desirable that the manufacturer provide ease of serviceability.

Serviceability is facilitated in this system by making all three counters identical in their internal layout, and by utilizing the same circuitry wherever possible in the serializer and output driver. All circuitry is contained on replaceable plug-in printed-circuit modules as shown in Figure 6. These modules are entirely free from adjustments of any type and may, therefore, be readily interchanged with other like modules within the same axis or between axes. In the event of failure of some type, an educated guess is made as to the circuit most likely to be malfunctioning. The circuit is then interchanged with another like circuit and a visual inspection is made to determine if the fault was corrected by the exchange of modules. Using this approach, it is possible for virtually any malfunction to be quickly corrected by entirely untrained personnel with no electronic background. It should be noted, of course, that the modules are instantly interchangeable being of the plug-in type, and spare modules may be maintained in the user's stock, or are readily available from Wang Laboratories on an exchange basis. The electronic chassis are mounted on slides for immediate access to the

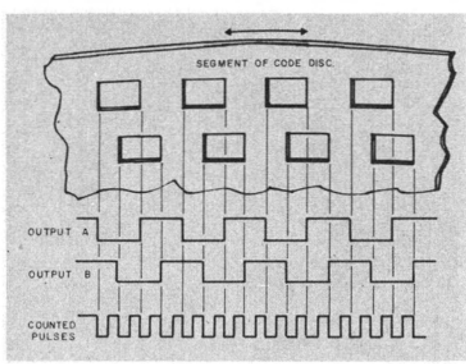

FIG. 4. Diagram depicting the operation of the encoder.

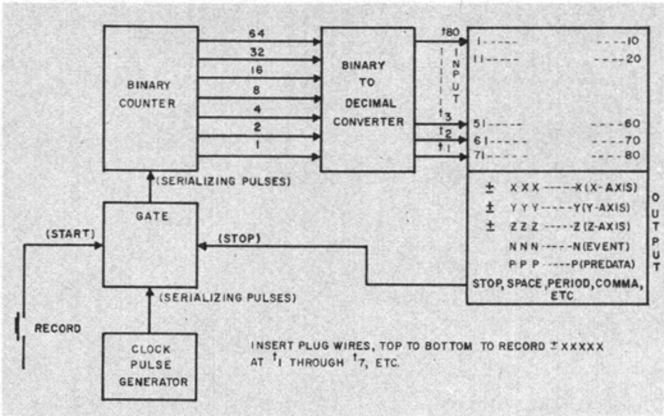

FIG. 5. Flow diagram of the Output Serializer.

circuitry. Long-life nixie tubes, which are easily readable and have a life expectancy of two years according to the tube manufacturers ratings, are used for the display.

IT MAY HAVE BEEN NOTED from the illustrations that the Coradograph was a fixed relationship to the B8 Aviograph and cannot be oriented in the direction of a particular right-of-way, which is possible in some other systems. This is not a limitation, however, because the relationship is always the same and a very simple computer routine transforms the axis orientation.

Many other applications of this system are obvious and some are already in use. For example, several models of the Faul/Coradi Coradographs with digital read-out and recording systems are currently being delivered. Other applications include comparators, spectrometers, film readers, precision measuring engines, strip chart recorders and X-ray diffraction equipment. It is possible with slight modifications to the system described to record automatically at present time intervals, or to record at preset intervals of displacement in each axis. Similar systems can be supplied with absolute rather than incremental encoders, and with code translators in place of bi-directional counters.

It is suggested that those who are interested should contact either Faul/Coradi or Wang Laboratories for specific information on other uses of these systems.

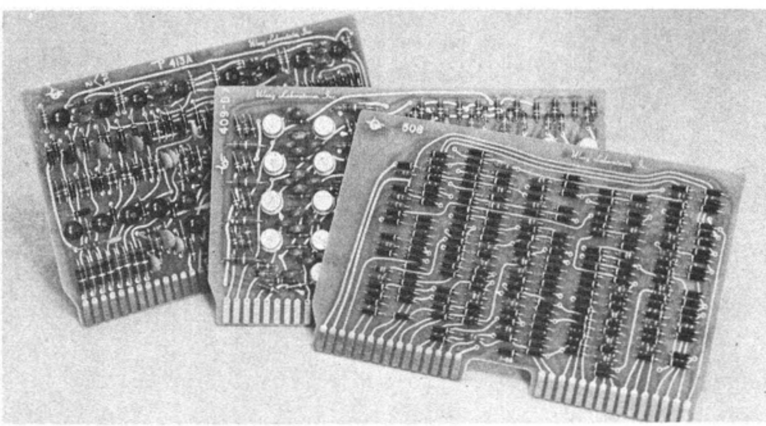

FIG. 6. Solid state circuit modules.